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Forest Insects and Pathogens Affecting The Redwood Mountain Giant Sequoia Grove, Sequoia National Monument

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Introduction/Background

Two sites within the Redwood Mountain Giant Sequoia Grove, were visited on May 13, 2002. Those present included Lew Jump, Forester, Sequoia National Forest; John Wenz, entomologist, Forest Health Protection (FHP), Stanislaus National Forest; and John Pronos, plant pathologist, (FHP), Stanislaus National Forest. The purpose of the site visit was to evaluate current and past tree mortality with respect to cause and conditions contributing to the mortality. This information could be helpful in formulating management options for giant sequoia groves.

Stop 1:

The first location visited was a 12-acre plantation established in 1986 adjacent to the District boundary with Whitaker Forest (University of California, Berkeley). This area experienced giant sequoia mortality in the mid 1990s, which was documented in FPM Report No. C96-7, "Armillaria root disease in a giant sequoia plantation on the Hume Lake Ranger District, Sequoia National Forest", dated August 15, 1996. At that time, *Armillaria mellea* (the biologies of diseases mentioned are described at the end of this report) was found to be the primary cause of mortality for 14 giant sequoia saplings that were approximately 8 years old. In addition, one 49" DBH overstory sequoia (GS #1) was dead from root disease. The first trees died in 1994 and no trees died after 1996.

While in the plantation this past spring, Lew Jump noticed another planted giant sequoia had recently died and requested a site visit from FHP. The recently killed tree was 5 inches DBH, 14 feet tall and located about 30 feet from the overstory sequoia that died in 1995 (GS#1). White mycelial mats of *A. mellea* were present at the root collar. Several nearby plantation trees were

found with off-color (reddish-green) foliage and cones in the very top of the crown. These were probably "stress" cones that formed after the sequoias were first infected by *A. mellea.* When examined at the root collar, all trees, except one, had fresh, viable mycelial mats. Our assumption was that all of these trees would die this summer.

Some of the off-colored trees in the plantation infected with *A. mellea* had current western cedar bark beetle, *Phloeosinus* sp., probably *punctatus,* (Coleoptera; Scolytidae) attacks on the bole. The adult galleries were less that 2 cm in length at the time of inspection; no eggs or larvae were observed. No *Phloeosinus* boring activity was observed on the boles of healthy (non "off-color") sequoia in the plantation. Western cedar bark beetles are generally considered to be secondary and usually infest only weakened, dying or downed trees. They are common in fallen giant sequoia branches. In addition, low levels of twig dieback were observed scattered throughout the plantation. Much of this is due to *Phloeosinus* adult feeding prior to initiating egg gallery construction.

A second overstory giant sequoia (GS #2), 55 inches DBH, located 120 feet down slope from GS #1 that died in 1995 had off-color foliage. When sampled just below the soil line, this tree also showed infection by *A. mellea.* The pattern and sequence of mortality suggest that the root pathogen may have spread via the roots of the first overstory sequoia (GS #1) to the down slope one, and now GS #2 is acting as a food base from which *A. mellea* is spreading to nearby saplings. Conifer to conifer spread of *A. mellea* in California is rare.

Stop 2.

The second area visited included several natural forest stands within the Redwood Mountain Grove between Eshom Campground and Whitaker Forest. Here we focused on locations that exhibited pockets of tree mortality. Stands were typical of low to mid-elevation (5200 ft.) mixed conifer type in the southern Sierra Nevada containing primarily ponderosa pine, white fir, California black oak and incense-cedar. Site class is generally between Dunning 2 and 3, and aggregations commonly exceed 300 sq. ft. of basal area per acre. Most overstory trees are in the 21 – 30 in. DBH diameter class, with a few exceeding 31 in. DBH

These stands have been harvested periodically, and Forest Service records show that three entries have occurred over the last 30 years: one for insect salvage in 1979 and two for sanitation in 1970 and 1985. Still, in general, stumps were not numerous on the sites we examined. Most of the dead trees observed reflect bark beetle-related mortality that has accumulated over the past several years, including that which occurred during the late-1980's to mid-1990's drought . Very little current mortality (that which occurred within the past year) was evident. One 8 in. DBH ponderosa pine was currently infested with mountain pine beetle, *Dendroctonus ponderosae* (Coleoptera; Scolytidae), and a 42 in. DBH ponderosa pine had about 30% of the live crown with currently fading foliage, probably due to attack by pine engravers, *Ips.* sp (Coleoptera; Scolytidae). In one location, dead trees resulted from windthrow within a seasonal drainage adjacent to a meadow and likely was due to saturated or shallow soils. The roots of these trees showed no evidence of root rot.

Localized concentrations of moderate to heavy defoliation to ponderosa and sugar pine advanced regeneration were observed. This defoliation was due to feeding by larvae of the silverspotted tiger moth, *Halisidota argentata* (Lepidoptera: Arctiidae). The silverspotted tiger moth overwinters as larvae and feeds on a variety of western conifers; damage is usually inconsequential in the general forest.

White pine blister rust, caused by the fungus *Cronartium ribicola*, was very common in the understory and scattered throughout the area. Sugar pine seedlings and saplings exhibited the most infection and included both lethal and non-lethal branch cankers and bole cankers. Aeica on branches and boles were actively sporulating.

Discussion/Conclusions

Bark beetle-related mortality levels vary through time and although levels of current mortality in the areas examined are low, periods of increased mortality can be expected, especially during periods of drought. Many of the stands in the Redwood Mountain Grove are currently overstocked which places them at additional risk to bark beetle attack. Depending on scale, bark beetle-related mortality can result in a variety of direct and indirect effects on forest stands and ecosystems. These effects include changes in stand density, species composition and structure, wildlife habitat, wildfire dynamics and commodity and/or amenity values. Management strategies and options, including preventive thinning, exist to help reduce unacceptable effects of bark beetle-related mortality and should be considered when developing silvicultural prescriptions to meet resource management objectives.

When removing trees in mixed conifer stands, however, two common root disease organisms may cause problems for the remaining conifers. Annosus root disease (*Heterobasidion annosum*) is normally associated with conifer stumps and Armillaria root disease (*Armillaria mellea*) usually originates on black oak stumps or snags: both pathogens can infect giant sequoia. Once established, these root parasites are very difficult, if not impossible, to remove from a site. Although annosus root disease is the more common and aggressive of these two organisms, new infections can effectively be prevented by treating true fir, Douglas-fir and giant sequoia stumps with Sporax immediately after cutting. There is no equivalent to Sporax for treating oaks to prevent pathogenic occurrences of Armillaria. In most cases, allowing oaks to remain alive and in place and not removing them is the most practical prevention for Armillaria.

White pine blister rust will eventually kill those sugar pine with lethal infections and cause new infections in healthy trees when environmental conditions favoring the fungus occur. This will result in stands that are almost devoid of seedling, sapling and pole-size sugar pines. Preventing blister rust infections in field situations is not possible and controlling rust once it is established is very difficult. For these reasons, Region 5 has chosen to emphasize putting genetically resistant sugar pine stock into the ecosystem whenever possible. Even though this is the desired action, current management direction does not provide many opportunities to plant rust resistant seedlings.

In summary, activities that may provide the most protection of sequoia groves against major forest pests include:

Pests	Treatment
Bark and engraver beetles	Preventive thinning
Annosus root disease	Treating true fir, Douglas-fir and sequoia stumps with Sporax
Armillaria root disease	Allowing black oaks to remain alive on site
White pine blister rust	Planting rust resistant sugar pine whenever possible

Biologies of Disease Organisms

Armillaria Root Disease

Fungi in the genus *Armillaria* are widely distributed in soils and usually live as saprophytes on dead wood or other organic matter. Until about 1980, it was thought that only the species *Armillaria mellea* existed in North America. Recent research, however, has shown that nine species may be present. In California, *A. mellea* is the most common species, followed by *A. gallica*. The following discussion refers to *A. mellea*.

This fungus has a wide host range, including virtually all woody plants in California. It is frequently associated with hardwood roots, especially oaks. Healthy oaks are resistant to the fungus. This resistance disappears, however, when trees are weakened, stressed, cut, or killed, and Armillaria may then rapidly colonize and decompose roots and sometimes entire root systems. Stresses that have been linked to increased damage from this root disease include insect defoliation, drought, excessive soil moisture, poor planting techniques, bark beetle attack, air pollution injury, and nutrient deficiencies.

The organic material used as a source of nutrition is called a food base. With a large food base to utilize, the fungus becomes more aggressive and moves to the roots of nearby trees by means of root contacts and rhizomorphs. Rhizomorphs are structures that resemble black shoestrings and grow like roots through upper soil layers. The predominant method of tree to tree spread in California is via root contact; rhizomorphs are more important and prevalent in other areas of the country.

Armillaria is capable of directly penetrating through the intact root bark of living trees, and once it reaches the cambium it usually grows rapidly, producing a flat, white, leathery, fan-shaped mycelial mat. Rhizomorphs are often associated with the mat. If the fungus reaches the root collar it girdles the stem and kills the tree. After Armillaria successfully colonizes a root segment or root system, it continues to decay the wood and causes a white to yellowish, wet, stringy rot. This rot does not usually extend up the stem more than a few feet above the soil line.

Clusters of mushrooms may be found in the fall at the base of infected dead or dying trees and stumps. These mushrooms may also grow directly out of the soil near the food base. Spores produced by fruiting bodies are not an important source of new infections or long distance spread.

White Pine Blister Rust

Blister rust (*Cronartium ribicola*) is caused by an obligate parasite that attacks sugar and western white pines and several species of *Ribes*. The fungus needs the two alternate hosts to survive, spending part of its life on 5-needled pines and the other on *Ribes*. The disease occurs throughout the range of sugar pine to the southern Sierra Nevada, but has not been reported further south. Infection of pines results in cankers on branches and main stems, branch mortality, top kill, and tree mortality.

Spores (aeciospores) produced by the fungus in the spring on pine bole or branch cankers are wind-disseminated to *Ribes* where they infect the leaves. Spores (urediospores) produced in orange pustules on the underside of the leaves re-infect other *Ribes* throughout the summer, resulting in an intensification of the rust. A telial spore stage forms on *Ribes* leaves in the fall. Teliospores germinate in place to produce spores (sporida) which are wind-disseminated to pines and infect current year needles. Following infection, the fungus grows from the needle into the branch and forms a canker. After 2 or 3 years, spores are produced on the cankers and are spread to *Ribes* to continue the cycle. Although blister rust may spread hundreds of miles from pines to *Ribes*, its spread from *Ribes* back to pines is usually limited to a few hundred feet.

Branch cankers continue to enlarge as the fungus invades additional tissues and moves toward the bole. Branch cankers within 24 inches of the bole will eventually form bole cankers (these are called **lethal** cankers). Bole cankers result in girdling and death of the tree above the canker. Cankers whose closest margins are more than 24 inches from the main bole are unlikely to reach the bole and only branch flagging will result (these are called **non-lethal** cankers).

Environmental conditions are critical for successful infection and limit the disease in most years. Moisture and low temperatures favor infection of both hosts, and must coincide with spore dispersal for infection to occur. In California, these conditions occur only infrequently, usually in cool moist sites such as stream bottoms or around meadows. In so called "wave years" when favorable conditions occur, high levels of infection can result. Wave years in California have occurred at approximately ten-year intervals in the past. As one moves from sites most favorable for rust to less favorable sites, the frequency of wave years decreases.

Annosus Root Disease In True Fir

Heterobasidion annosum (formerly *Fomes annosus*) is a fungus that attacks a wide variety of woody plants. All western conifer species are susceptible. Madrone and a few brush species (*Arctostaphylos* spp. and *Artemisia tridentata*) are occasional hosts, while other hardwood species are apparently not infected. The disease has been reported on all the National Forests in California, with incidence particularly high in true fir stands that have been repeatedly logged. Disease frequency tends to be higher in older stands with large fir and high basal areas (over about 330 square feet/acre).

During periods favorable to the fungus, fruiting bodies (conks) form in decayed stumps, under the bark of dead trees, or under the duff at the root collar. New infection centers begin by aerial spread of spores produced by the conks and subsequent colonization of freshly cut stump surfaces or wounds on living trees. The fungus then spreads through root contacts into the root systems of adjacent live true fir. Local spread of the fungus from a stump typically results in the formation of a disease center, with dead trees in the center and fading trees on the margin. These centers usually continue to enlarge until they reach natural barriers such as stand openings or non-susceptible plants.In pines, *H. annosum* grows through root cambial tissue to the root crown where it girdles and kills the trees. In less resinous species such as true firs, the fungus sometimes kills trees, but more frequently it is confined to the heartwood and inner sapwood of the larger roots where it causes a chronic butt and root decay and growth loss. Thus, while infection in true fir usually does not kill the host, it does affect its growth and thriftiness. Losses

in true fir from *H. annosum* are mainly the result of windthrow because of root decay, and reduced root systems that predispose trees to attack and eventual death by the fir engraver beetle. Field observations suggest that vigorous young firs are usually able to regenerate root tissues faster than they are lost to the root disease. But when true firs slow in growth because of stand and/or site conditions, root development decreases to where there is a net loss in roots and the trees slowly decline due to the gradual loss of their root systems. This decline may take 10 to 20 years before tree death occurs.

There are two pathogenic strains of the fungus that differ in their ability to infect various conifers in California. The "P" or pine type infects and kills all pines (although susceptibility of pine species vary), in addition to incense-cedar and western juniper. The "S" or fir type infects true fir, Douglas fir and giant sequoia. Knowing which type is active in a stand is important, and will allow favoring alternate conifer species because the fungus strains do not cross infect between the two groups listed above.